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The Environmentally Friendly Practices to Fight Plants' Diseases: Scope Review

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Plant diseases reduce the production and affect the food security. The use of synthetic chemicals affects the environment and individual health quality. The environmentally friendly practices were found the solution to minimize the side effects of pesticides and herbicides. This review aims to investigate the impact of environmentally friendly practices on plant disease protection. The results showed that environmentally friendly practices are very effective in controlling plant diseases and the same time reducing the environmental impacts and the individual's health. These practices were found to be effective in improving the plant product and maximizing the economic profitability of the agricultural practices. These practices will increase the sustainability of the agricultural processes.

Keywords: Environmentally friendly practices, plant diseases, cultural practices, biocontrol practices, economic profitability.

INTRODUCTION

Combating plant diseases is crucial for plant production, but it should be accompanied by implementing environmentally friendly practices (EFP) to preserve human health and the ecosystem. The EFP in agriculture refers to all the strategies that are used to minimize the ecological impact and promote sustainability (Rebouh *et al*., 2023), while the biocontrol reflects the usage of living organisms including parasites, pathogens, and natural predators to manage pest populations and diseases (Thilagam *et al*., 2023). Duart *et al*. (2023) reported that the excessive use of synthetic chemicals in agricultural practices will negatively impact the environment and health concerns. Librizzi *et al*. (2022) discussed that alternative strategies including the utilization of natural products and microorganisms can be promising solutions to control plant diseases without the residual effect of chemical pesticides. On the other hand, Olufolaji and Ajayi (2021)reported that organic management practices showed successful management of plant diseases, besides offering a cost-effective, non-toxic, and eco-friendly approach to agricultural practices. Kekalo (2022) reported that the use of biofungicides and the reduction of chemical use played an important role in protecting from diseases like root rot encouraging the use of sustainable and ecologically sound methods to be used in agriculture. The organic management techniques, the natural compounds, and microbial diversity will contribute to enhancing crop production and reserve environmental sustainability in agriculture. Several practices can be implemented to combat plant diseases using environmentally friendly techniques (EFT). Cultural practices including crop rotation, intercropping, proper spacing between plants, and selecting the planting sites play a crucial role in disease prevention (Kutama *et al*., 2022). The soil solarization and biofumigation with brassicaceous green manures showed effectiveness for controlling Fusarium and nematode diseases in tomatoes and cucumbers which will reduce root galling and disease incidence leading to maximizing crop production (Al-Abed *et al*., 2022). Furthermore, the utilization of microbial metabolites from soil microorganisms, particularly bacterial strains like Pseudomonas, has demonstrated exceptional biocontrol activity against common plant pathogens, offering a promising alternative to synthetic chemical products for disease management (Librizzi *et al*., 2022). Overall, integrating these practices can significantly contribute to sustainable agriculture by reducing the reliance on harmful agrochemicals and promoting environmentally friendly disease control strategies. The literature raised the importance of using eco-friendly practices in agriculture to reduce plant diseases. These practices use microbial biocontrol agents and biotechnology approaches side by side with sustainable agricultural techniques (Mukherjee 2020; Fenta *et al*., 2023; Hamdi and Alzawi, 2023; Jehangir *et al*., 2022). With the introduction of these friendly practices, most of the literature concentrated on the reduction of using synthetic chemicals

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and the use of promoting pest control solutions will work effectively to control diseases and improve plant production side by side with preserving health and environment. With the dramatic increase in pollution and the climate change conditions side by side with the efforts of preserving human health and the sustainability of agricultural production, the demand for eco-friendly systems increased. The adoption of eco-friendly systems including the adaptation, mitigation, and anticipation strategies enabled reserving agricultural sustainability and reserve the environment (Sutriadi *et al*., 2022). The environmentally friendly practices are very wide including the use of organic amendments including manure and bio-fertilizer and implementing sustainable practices to mitigate environmental risks (Patel *et al*., 2023). The use of traditional chemicals produces high microbial resistivity which leads to resistance among the plant pathogens (Miller *et al*., 2022). The high resistivity of plant pathogens will require the use of extra amounts to reach the required results which, on the other side, affect human health and environmental degradation consequences (Hou *et al*., 2022; Almeida *et al*., 2023). Some added chemicals reduce the plant's resistance to diseases such as orysastrobin against bacterial pathogens (Hou *et al*., 2022). In most cases, the agricultural practices target the increase of production. Under most of these practices, more than one target can be achieved besides the economic benefits. For example, the greenhouse technology provides a protected environment for plant growth which increases production and reduces the pest and plant disease pressure side by side optimizing the resource utilization and leading to higher production (Singh *et al*., 2024). The use of plant-growth-promoting rhizobacteria and biological control agents in soil inoculation will enable the effective management of plant diseases and produce sustainable agricultural practices (Mehmood *et al*., 2023). Other practices related to proper variety selection, and quality seeds, side by side with efficient nutrient and water management will improve the plant's resistivity to disease, and improve production and reserve environment (Jehangir *et al*., 2022). The friendly environmental practices in agriculture do not contradict the core of businesses related to the economic benefits. The plant diseases were found to produce high economic losses in agricultural businesses (Sankhe and Singh, 2022). The protection will improve the plant production and improve the food security (Keshava Murthy *et al*., 2022). Plant diseases may lead to more than 50% losses in yield, which in some cases leads to the use of unsuitable pesticides that adversely affect the soil, production, and human health (Shinde and Singh, 2022). The traditional methods of disease detection and physical inspection are time-consuming and expensive methods, which can be controlled by the computer systems in modern agricultural practices reducing disease distribution and minimizing the cost of protection (Bagban *et al*., 2023). To combat these challenges, ongoing research focuses on developing innovative methods such as microbial biocontrol agents and chemicals to prevent and treat plant diseases, ensuring better crop quality and increased agricultural yield in the future (Kaur and Sharma, 2021).

MATERIALS AND METHODS

The study concentrated on the use of friendly alternative methods to control plant diseases in a way to preserves human health and improves production. For the literature review and results, the study searched databases including web of Science, Scopus, AGRICOLA, and Google Scholar. The period of research was from January 2014 to May 2024. The general search terms utilized in searching the databases included EFP to control plant diseases, the interaction of EFP impact on plant diseases, the impact of EFP on environment and human health, and the economy of using EFP in plant disease control. The inclusion criteria included; the research concentrated on alternative methods to control diseases. The studies within the timeframe of 2015 and 2024 were considered. The English language papers only were considered in this search. The exclusion criteria included the papers outside the timeframe and the ones that are not related to this study. The papers were classified according to their topics related to this study. The total number of papers found was 1470 papers. After screening the papers according to the previous criteria, the total number of papers included was 550 studies. The eligibility stage was the filtering of the eligible articles reaching 45 studies. In the final stage, the total number of studies included was 33. Figure 1 shows the different research stages and the inclusion and exclusion of papers. It introduces also the filtering processes to reach the targeted papers.

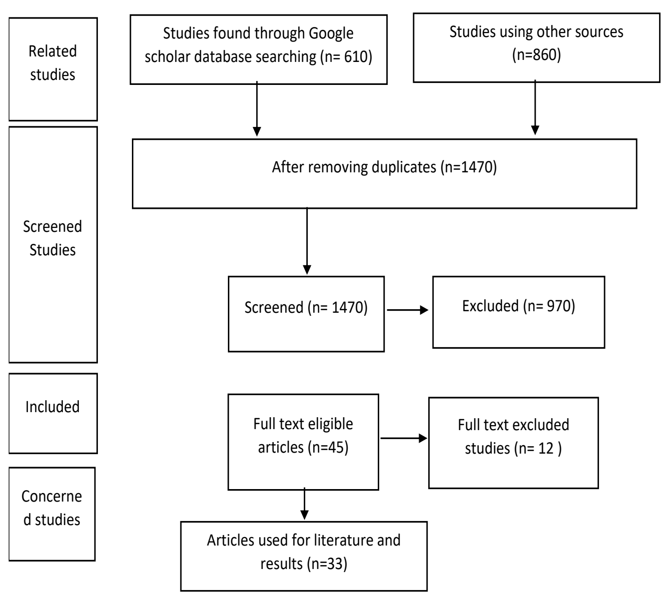
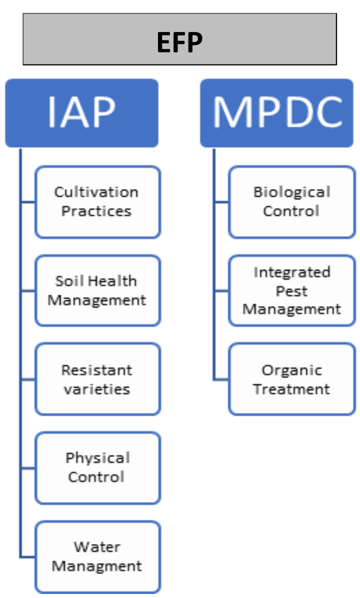


Figure 1. Flowchart of sources assessment.

RESULTS

***The EFP to control plant diseases*:** The purpose of using EFP does not contradict the purpose of practicing agricultural activities as the EFP maximizes the purpose related to production. The EFP's purpose is to mitigate the negative impacts of using chemical pesticides which became of low efficient with time and at the same time it eliminates environmental contamination and reserve health (Verma *et al*., 2023; Nigar *et al*., 2023; Ziedan, 2022). The eco-biocontrol practices aim at using biocontrol agents beneficial bacteria and natural components which support the plant health and the production process (Verma *et al*., 2023; Ziedan, 2022). Moreover, eco-friendly pesticides will encourage biodiversity preservation, evolve economic benefits, and improve public health and safety (Verma *et al*., 2023). The use of natural resources for plant disease protection will help in reaching sustainable agricultural systems (Ziedan, 2022). The EFP to control plant diseases according to literature was classified into major 8 practices. These practices are related to two major categories. The first is related to the inputs of the agricultural practices (IAP), while the other one is related to the management of the plant disease causes (MPDC). The EFP starts from the preparation stage to the end of the cropping season including protection measures at each stage, while the MPDC practices continue from the start till the end of the growing season. The IAP is related to land preparation, the selection of the proper places, water management, and physical practices to control diseases. Related to the MPDC, the EFP practices include the use of all possible approaches to protect or control plant diseases (Figure 2).



Source: Prepared by author based on literature

Figure 2. The classification of EFP to control plant diseases.

Cultural practices and soil management are considered very important in protecting from plant diseases. Some cultural practices including minimum soil disturbances, the continuous soil cover with crops, and the intercropping system will help in reserving the microbial diversity, create suppressive soils, reduce disease pressures and it will disrupt the cycles of soil-borne pathogens (Prashanth and Murali, 2023). Moreover, the agroecological approaches promote soil health, landscape heterogeneity, and vegetation diversity which help in disease protection (Vega *et al*., 2023). These practices will improve plant health and minimize the need for chemicals to control plant growth (Yildirim, 2023; Kutama *et al*., 2022). The ecosystem balance can be reached through habitat measurement, resistance crop varieties, and biocontrol agents (Brotodjojo and Lakatos, 2022). Table 1 presents the mechanism of pathogen levels reduction associated with cultural practices.

The resistant varieties and the biological control are crucial in protecting from diseases and promoting sustainable agricultural systems (Zeilinger, 2023). The biocontrol agents form eco-friendly and natural alternatives for chemicals which will contribute to environmental preservation and leave zero residues in food (Zeilinger, 2023; Reuveni, 2023). The resistant varieties with the other practices will reduce the disease in plants through the improvement of plant resistivity for pathogens (Clin *et al*., 2023). Table 2 explains the mechanisms of different plant disease management mechanisms.

***The efficiency of EFP and plant diseases*:** Different studies investigated the efficiency of EFP practices in controlling plant diseases. The studies investigated the efficiency of biological control agents on plants' disease control. The results showed that the efficiency was high and minimized the use of chemicals in plant disease control (Hamdi and Alzawi, 2023; Mukhamadiyev *et al*., 2023). The studies that used fungal and bacterial biocontrol agents to replace synthetic chemicals showed a high ability to prevent diseases (Hamdi and Alzawi, 2023). Other research has shown that the use of beneficial bacteria strains resulted in promising results in plant disease control (Gordani *et al*., 2023; Wang *et al*., 2023). Other studies investigated the efficiency of applying EFP strategies such as moving winter fallen leaves side by side or using biological agents led to efficient results in reducing fruit spots and leaf blotch which replaced the chemical for control (Cabrefiga *et al*., 2023). Some studies related to soil management found that the efforts related to soil microbial diversity have figured out that some bacterial strains produce metabolites that combat plant pathologies effectively (Librizzi *et al*., 2022). Prashanth and Murali (2023) reported that minimum tillage and crop rotation were very efficient in reducing disease pressure. Leveraging soil conditions to predict disease outbreaks using machine learning models to study the soil properties and disease severity will lead to a cost-effective and sustainable approach to disease

Table 1. The effect of soil cultural practices on soil-borne pathogens.

Cultural practice	Impact on pathogen levels	Mechanism	Source
Crop rotation	Decreases	Breaks pathogen life cycle by alternating host plants	(Prashanth and Murali, 2023)
Tillage	Mixed	Exposes pathogens to air and disrupts soil structure	(Shahi *et al*., 2020)
Cover cropping	Decreases	Enhances beneficial microbes and suppresses pathogens	(Roberts *et al*., 2021)
Organic amendments	Decreases	Increases soil biodiversity and pathogen antagonists	(Cha *et al*., 2024)
Monoculture	Increases	Continuous presence of the same host plant fosters pathogen build-up	(Ahmad and Hishamuddin, 2022)

Table 2. The mechanisms of plant disease management on disease pathogens.

Management Mechanism	Targeted disease cause	Mechanism of action	Source
Crop Rotation	Soil-borne Pathogens	Disrupts the life cycle of pathogens by changing host availability	(Larkin, 2021)
Resistant Varieties	Pathogen Infection	Uses plant varieties bred for resistance to specific pathogens	(Rebouh *et al*., 2023)
Biological Control	Pathogen Proliferation	Introduces natural predators or antagonists to suppress pathogens	(Fenta *et al*., 2023)
Chemical Fungicides	Fungal Pathogens	Directly targets and kills fungal pathogens on plant surfaces or soil	(Gordani *et al*., 2023)
Sanitation Practices	Pathogen Spread	Removes or disinfects infected plant material to prevent pathogen spread	(Prajapati *et al*., 2020)
Solarization	Soil-borne Pathogens	Uses solar heat to sterilize the soil, killing pathogens	(Al-Abed *et al*., 2022)
Integrated Pest Management (IPM)	Multiple Pathogens	Combines cultural, biological, and chemical methods to manage disease	(Safvan, 2024)
Mulching	Moisture Retention and Soil Health	Enhances soil moisture and suppresses weed growth, reducing disease occurrence	(Kaur and Sharma, 2021)
Grafting	Soil-borne Pathogens and Pests	Uses disease-resistant rootstock to protect susceptible scions	(Li and Zhao, 2021)
Quarantine and Regulation	Introduction of New Pathogens	Prevents the introduction and spread of non-native pathogens	(Tasrif *et al*., 2021)

management (Jyothi and Lingam, 2023). One more efficient activity was found by incorporating organic matter which enhances microbial diversity, nutrient availability, and disease reduction (Keloth *et al*., 2022).

***The economic efficiency of using EFP to control plant diseases*:** The economic efficiency of using EFP to control plant diseases forms a focal point in the current research. Some studies found that the use of biological control agents was economically efficient in improving crop production and maximizing profitability side by side with the reservation of agricultural sustainability (Hamdi and Alzawi, 2023; Rebouh *et al*., 2022). Rebouth *et al*. (2022) have found that the bioagents with a low dose of fungicides using integrated crop protection (ICP) systems were very efficient in reducing wheat diseases leading to higher production and quality, and so leading to maximized economic profitability. The use of eco-friendly pesticides was effective in controlling diseases, reducing environmental contamination, and improving economic profitability (Verma *et al*., 2023). Soil management practices were approved as efficient economic practices that can be used in agriculture. The conservative tillage, crop rotation, and organic amendments will lead to suppressive soils and reducing the diseases side by side with maximizing the plant production and economic profitability (Prashanth and Murali, 2023; Yadav *et al*., 2023). The machine learning-based approaches were found to be economically efficient in maximizing economic profits through maximizing production (Nigar *et al*., 2023). Ion some conditions, the research found that the integration of the traditional practices with the utilization of beneficial soil microbial communities side by side with organic amendments will improve crop production leading to maximization of the profits and environment control (Yadav *et al*., 2023; Nigar *et al*., 2023).

DISCUSSION

The objective of this paper is to review the role of ENP in fighting plant diseases in a way that accomplishes the original objective of the agricultural process and at the same time preserves the environment and human health. The

environmental issues and the human diseases that resulted from the traditional practices became a core issue that should be raised and investigated deeply through the introduction of new approaches that can establish food security and at the same time preserve the environment and human health. The results showed that the traditional methods of agricultural practices leave a high negative impact on the environment and human health through the high residues left in the food and soils. The studied researchers agreed that booth soil management, plant management, and biocontrol management have shown that the EFP produces positive effects on the control of plant diseases side by side with the reservation of the environmental conditions and human health (Nigar *et al*., 2023; Prashanth and Murali, 2023). The investigated studies have shown that soil management practices will enrich the beneficial bacterial species that will improve plant growth and increase plant production (Olufolaji and Ajayi, 2021). The EFP was found to integrate to help in plant diseases and lead to sustainable agricultural production. Pest management and agroecology are the bases of the EFP to control plant diseases. Agroecology considers the agricultural system as ecosystem. The ecosystem of agricultural composed of soil, plants and pests (Yan *et al*., 2023). Under the ecosystem of agriculture, plant health is reached through the use of ecological processes, natural cycles, and biodiversity. The integrated pest management is considered very crucial in agroecology which combine the biological, physical, cultural and chemical tools to control plant diseases with very minimum impact on environment. These systems aim to control plant diseases through the improvement of natural defenses, using chemical controls and promote beneficial organisms (Duarte *et al*., 2023). The effectiveness of the ecological practices is dependent on the ecological resilience that resulted in diverse and balanced ecosystems. These systems depend on the balance between the maintaining agricultural practices and the environment. The traditional method of plant diseases control relied on the use of chemical pesticides which harms the environment including soil degradation and water contamination (Yildirim, 2023). On the other side, the use of EFP, and plant disease can be controlled with environmentally friendly practices. Under the traditional practices, the plant disease causes gain resistivity which reduce the effectiveness of using traditional method to fight diseases. The value of the crop products using the traditional methods is of less quality compared to the EFP. The integration of IAP and MPDC practices will provide the opportunity to integrate the EFP practices by going through the selection of the best crop planting procedures and integrating them with biocontrol practices to improve plant resistivity and reduce plant diseases. The results showed that some simple practices can reduce plant diseases such as the use of local irrigation systems (drip irrigation) will reduce the opportunity for exposure to plant diseases by reducing the environment of disease pathogens (Vega *et al*., 2023). The plans for EFP start in the earlier stages of practicing agricultural activities. The research has shown that adopting previous plans to apply EFP is very important to integrate the different stages of plant growth and agricultural activities. The design of soil management, the selection of varieties resistant to plant diseases, the design of irrigation systems, and the other biocontrol practices are considered very important for planning before the applications (Gordani *et al*., 2023). The adoption of new technology systems will enable the management of agricultural activities and the adoption of earlier warning systems will improve plant disease control. The adoption of automatic systems was found to help in controlling plant diseases and improve plant production. These systems were tested through different studies and proved their efficiency in plant disease control (Molad *et al*., 2021). In traditional practices, the researchers found that the use of some practices such as utilizing organic materials will help in reducing plant diseases. Even in traditional agricultural practices, the adoption of practices to reduce diseases is possible and improve crop production. On the other side, the researchers approved the economic feasibility of the adoption of EFP practices through the increase of crop production and improve the profitability of the agricultural processes.

***Conclusion*:** The objective of this review paper is to highlight the impact of EFP on the protection of plant diseases. The EFP practices to protect plant diseases are related to cultivation practices and biocontrol practices. The EFP practices were found to reduce the disease pathogens and increase production. The results showed that the economic profitability produced by the practice EFP practices was approved in different research resulting in the maximization of plant production and decrease the plant losses resulting from plant diseases. The cost variation of the inputs of EFP practices will have an impact on the costs but the returns will be increased through the maximization of the production. Even in the traditional practices the intervention of some EFP will help in controlling plant diseases and improve production. The results showed that EFP practices are very essential to having sustainable agricultural practices, protecting against diseases, and preserving human health. Future research should consider linking modern technology practices in agriculture with controlling plant diseases such as early diagnosis using electronic systems of symptoms.

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